

*Total Solar Eclipse, 1905, August 29–30. Preliminary Report of  
the Observations made at Guelma, Algeria.*

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(Received November 17, 1905.)

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§ 1.—*Introductory. Choice of Station.*

The expedition to which this report refers was one of those organised by the Joint Permanent Eclipse Committee of the Royal Society and the Royal Astronomical Society; it was supported by a grant made by the Government Grant Committee.

Guelma was chosen for the site of the observations, as being an inland station between Stax, which was selected for an expedition from the Royal Observatory, Greenwich, and Philippeville, which it was at first expected Sir Norman Lockyer would occupy. Guelma is 58 kilometres from Bona, 65 kilometres from Philippeville, 55 kilometres from the nearest coast of the Mediterranean Sea; it lies at a height of about 1200 feet above sea-level on the south side of the Valley of the Seybouze, amongst hills which range in height from about 3100 feet at 13 kilometres to the north, to about 4700 feet at 11 kilometres on the south, where lies the celebrated mountain, Mahouna,

"the sleeping lady," so called from the resemblance of its silhouette to the form of a woman. (For the position of the observing hut, see p. 59.)

At the end of November, 1904, I had made enquiries from M. Trépied, the Director of the Algiers Observatory, about the meteorological conditions to be expected in Eastern Algeria at the end of August. M. Trépied replied in a way that recalled very vividly the cordial welcome which he extended to Professor Turner, Mr. Wesley, and myself at Algiers on the occasion of the total eclipse of the sun, 1900, May 28. The information, which he kindly collected from the Service Météorologique de l'Algérie, encouraged the idea that Guelma was a desirable station to occupy, and, though the chances of perfectly favourable conditions at the end of August were not high, yet, when expressed in statistical form, they appeared vastly better than our actual experiences in the week which included the eclipse day. The following record of weather conditions about 1 to 2 o'clock (the hour of the total phase of the eclipse was two o'clock), makes it clear that the expedition was very fortunate:—

|            |            |                                      |
|------------|------------|--------------------------------------|
| Friday,    | August 25. | Storm, rain and cloud.               |
| Saturday,  | " 26.      | Sky completely clouded.              |
| Sunday,    | " 27.      | Violent thunderstorm and dust storm. |
| Monday,    | " 28.      | Sky completely clouded.              |
| Tuesday,   | " 29.      | Sky considerably veiled by cloud.    |
| Wednesday, | " 30.      | Superbly clear sky (eclipse day).    |
| Thursday,  | " 31.      | Sky completely clouded.              |

Fortunately at other hours on most of these days there was plenty of sunshine available for the adjustment of the various instruments. The record for the previous fortnight that we were at Guelma was much more favourable, with something like 11 clear days and three clouded about the eclipse hour.

I accepted M. Trépied's invitation to share the opportunities afforded by the municipal authorities of Guelma, and to install our instruments in the grounds of the Boys' School of the Commune; and the observations were accordingly made within a few yards of the installations of the Algiers expedition under M. Trépied assisted by Messieurs Rambaud, Sy, and Renaux, and of the Marseilles expedition, consisting of Messieurs Stephan and Borelly, assisted by Dr. P. Stephan.

The school enclosure, with its shady trees and its capacious class-rooms and covered promenades, which M. Bachotet, the genial director, encouraged the various expeditions to use, proved an admirable site not only for the eclipse operations, but also for the undisturbed preparation and adjustment of the instruments.

§ 2.—*Facilities.*

The expedition is indebted to the French authorities for facilities in taking the instruments into Algeria free of duty and of inspection at the Custom House; to the Sous-Préfét de l'Arrondissement, and to the municipal authorities of Guelma for their kind permission (strengthened by every friendly attention to further the objects of the expedition) to install the instruments in the yard of the École Communale; to M. Joly, Délégué financier; to M. Trépied, the Director of the Algiers Observatory, for his ever ready aid; to M. Bachotet, the Director of the School, who devoted his summer vacation to assisting the expeditions to utilise the school premises to the best advantage; to the Peninsular and Oriental Steam Navigation Company for their liberal arrangement by which the cases of eclipse instruments were transported free of charge from London to Marseilles and back.

§ 3.—*Personnel.*

I have great pleasure in acknowledging an unusual amount of volunteer assistance in the eclipse operations. To Mr. Lewis Wallace I am under great obligations, not only for the admirable way in which he carried out his important part in the programme of observations on the day of the eclipse, but also for his unstinted assistance in setting up the instruments. He travelled out to Algeria as a volunteer, and his aid from the beginning (August 8) of the preparations until the completion (September 12) of the repacking of the instruments was invaluable, all the more so on account of his experience in Sumatra in the eclipse of 1901.

Mr. H. H. Champion, of Uppingham, joined our party at Guelma on August 24, and gave valuable help in the final preparations. Rev. A. H. Cooke, Headmaster of Aldenham School, and Mr. J. Mello Wadmore, M.A. (Oxon), F.C.S., Science Master at Aldenham School, arrived at Guelma on August 28, and at once took part in the rehearsals of the eclipse operations, in which Mrs. Newall also joined. It is a great pleasure to acknowledge my indebtedness to all for their valuable assistance. The part that each took in the observations will appear later on in this report.

§ 4.—*Itinerary and Summary of Diary.*

- July 28. Departure from England on board of the P. and O. ss. "Egypt,"  
via Gibraltar to Marseilles.
- August 3. Arrival at Marseilles.
- „ 4. Arrangements about transport of instruments.
- „ 5. Left Marseilles with instruments on ss. "Ville d'Oran."

- August 6. Arrival at Philippeville, 6 P.M.  
„ 8. Arrival at Bona, 4 A.M., and at Guelma, 6 P.M.  
„ 9. Instruments delivered at the École Communale. Site chosen.

The following three weeks were very fully occupied with setting up the pillars, the tent, and the instruments. In spite of the complete preparation of the instruments before they left England, the time allowed for setting them up in adjustment was found full short; two more days after the rehearsals would have been a welcome addition to our time of preparation, in allowing leisurely final arrangements of the various items of the programme. The day temperatures were commonly over 90° F., and several times over 105°, twice 109° was recorded. The air was usually very dry.

- August 28. First rehearsals in afternoon.  
„ 29. Rehearsals in morning, afternoon, and in twilight and in the dark.  
„ 30. The day of the eclipse. Weather conditions perfect.

Shortly after the eclipse, I despatched the following telegram to the Royal Society :—

“ Superb weather conditions at Guelma. Observations successfully made. Brilliant corona. Polar streamers remarkably long, extending towards Mercury over three degrees. Corona of maximum sun-spot type, but unusual dark rays. Splendid prominences.”

The next week was devoted to developing all the photographs taken during the eclipse, and in taking subsidiary photographs and observations requisite for the proper interpretation of the eclipse results.

- September 5. Dismantling and repacking of instruments begun.  
„ 11. Cases closed and despatched *via* Bona for Marseilles.  
„ 12. Departure from Guelma *via* Constantine for Philippeville.  
„ 16. Arrival at Marseilles. Arrangements about transport of instruments to London.  
„ 18. Arrival at Cambridge, with eclipse photographs.  
„ 27. Delivery of instruments at Cambridge, in sound condition.

#### § 5.—*The Position of the Observing Station.*

In the list of observatories given in the ‘*Connaissance des Temps*’ the position of the mosque at Guelma, as determined in the trigonometrical survey, is :—Latitude, 36° 27′ 55″ N.; longitude, 5° 5′ 34″ (0 h. 20 m. 22·3 s.) E. of Paris. From the large-scale town map of Guelma, which by the kindness of the municipal authorities I was able to study, the site of the observing hut was

found to be 400 metres from the mosque in the N.E. quadrant, and the northerly and easterly components were respectively 76 metres and 393 metres; whence the angular values are found to be  $2''\cdot5$  and  $15''\cdot9$ . Thus, taking the difference of longitude between Paris and Greenwich as  $2^{\circ} 20' 14''\cdot4$  (0 h. 9 m. 20·9 s.), we have for the position of the hut where the observations were made :—

Latitude .....  $36^{\circ} 27' 57''\cdot5$  N.  
 Longitude ...  $7^{\circ} 26' 4''\cdot3$  } E. of Greenwich.  
 0 h. 29 m. 44·2 s. }

According to the details given in the Eclipse Circular (No. 19) of the Nautical Almanac Office, the line of central totality would pass about 2 miles to the south of the observing station.

#### § 6.—*Time Observations.*

By the kindness of M. Trépied and M. Rambaud I was able to compare my chronometer watch (Frodsham, 1862) with the chronometer of the Algiers Expedition. M. Stephan also was good enough to compare my watch with his chronometer (Vissière, No. 63) just after first contact, which I did not observe. These comparisons gave the following results for the error of my watch :—

|       |            | Error. |    |      |
|-------|------------|--------|----|------|
|       |            | h.     | m. | s.   |
| (i)   | August 30. | 0·8    | —3 | 47·4 |
| (ii)  | „          | 5·2    | —3 | 49·4 |
| (iii) | „          | 23·2   | —3 | 50·9 |

The following table gives a comparison between predicted and observed times of the contacts, the “predicted” being calculated from the ‘Nautical Almanac’ :—

|                    | Position angle. | Guelma mean time. |    |      |           |    |    |
|--------------------|-----------------|-------------------|----|------|-----------|----|----|
|                    |                 | Predicted.        |    |      | Observed. |    |    |
|                    |                 | h.                | m. | s.   | h.        | m. | s. |
| First contact..... | 296             | 0                 | 43 | 56   | —         | —  | —  |
| Second „ .....     | 114             | 2                 | 3  | 49·6 | 2         | 3  | 22 |
| Third „ .....      | 297             | 2                 | 7  | 23·3 | 2         | 7  | 4  |
| Fourth „ .....     | 115             | 3                 | 20 | 22   | 3         | 20 | 7  |

The observed time of second contact is that when the signal, “Go,” was given by Mr. Wallace, who was observing the disappearing crescent on the

blue-glass focussing screen of the Dallmeyer telephotographic camera. My exposures with the grating camera at recorded moments give results which lead me to believe that the signal was correctly given.

The observed time of third contact is that recorded by Mr. Wallace when he was looking at the corona through a direct-vision prism, and saw the bright crescents disappear. It seems to me that this time may possibly be five seconds late.

The fourth contact was observed by me through the theodolite attached to the cœlostæt, Mr. Champion recording with my watch. I think my call was between 5 and 10 seconds late.

#### § 7.—*General Description of the Installation.*

Provision was made for making (A) a few visual observations, but the chief work was (B) the collection of photographic records of various phenomena during the total phase of the eclipse:—

A. The visual observations were to relate—(i) to the extensions of the longer streamers, and special attention was to be devoted to extensions in the direction of the planet Mercury, which the ephemerides showed would be at a distance of about  $4^{\circ}$  from the sun in a direction not far removed from that of the prolonged projection of the solar axis (for details, see p. 62); (ii) to the plane of polarisation of the earth's atmosphere during the eclipse as determined by means of a properly mounted Savart polariscope; these observations were to be utilised for setting the polarisers used for the photographic records (for details, see p. 63).

B. The photographic work all involved the use of clockwork for giving stationary images of the corona. And, as two clocks were utilised, the installation may be best described in general terms as consisting of two divisions—(i) a powerful spectrograph (see p. 64) and (ii) a set of seven varied instruments, all fixed closely together, and pointed in the proper direction towards a cœlostæt, which, being driven by clockwork, gave a stationary image of the corona in each of the instruments. The first instrument was devoted to an attempt to photograph the spectra of the eastern and western equatorial regions of the corona in order to provide means for deducing the velocity of rotation of the corona. The object of the second group of instruments was to get—(i) photographic records of the forms and extension of the streamers of the corona, and also to provide material for a study of the brightness of the corona at different distances from the sun, in continuation of work which was inaugurated by the Committee several years ago, and to which Abney, Thorpe and Turner have mainly contributed by their researches; (ii) photographic records of the phenomena of polarisation

of the corona by three modes of attack; and (iii) photographic record of the flash spectrum under very high dispersion by means of an objective grating spectrograph.

Preliminary notes of each of these lines of investigation will now be given.

§ 8.—*Visual Observations. Extension of Coronal Streamers, etc.*

*Extension of Coronal Streamers.*—The corona was obviously of the type associated with the maximum in the sun-spot cycle. The absence of anything like polar features accompanied by marked equatorial extension of the corona was noted by all the observers. The general brightness of the corona was distributed round the whole limb to approximately the same radial distance except for four or five marked streamers. The longest of the prominent streamers were those which appeared close to the south pole of the sun. The estimates of extension differed very much:—

| Observer.     | Estimate of extension of<br>southern streamers. | Stars and planets seen. |
|---------------|-------------------------------------------------|-------------------------|
| H. H. C. .... | $1\frac{1}{2}$ diameters.                       | Regulus, not Mercury.   |
| A. H. C. .... | No estimate.                                    | Mercury seen.           |
| H. F. N. .... | Four-fifths of way from $\odot$ to $\oslash$ .  | Mercury seen, no stars. |

Mr. Champion prepared charts showing the relative positions of the sun and Mercury, and some bright stars; and during the eclipse he noted down the general positions of the main streamers. These recorded positions coincide remarkably well with the streamers shown on the photographs. He, like myself, was struck by the fact that the easterly edges of two prominent streamers, one above, the other below the sun, seemed to be in continuous line approximately tangential to the sun's limb—an observation which is not completely borne out by the photographic records. But the extensions indicated in his sketch are in no case greater than  $1\frac{1}{2}$  diameters.

For my own part, I devoted my attention to following out the extension of the streamers in the direction of Mercury to their furthest traceable limit. These two streamers, together with one on the east side, at once struck my attention because each seemed to be flanked by a dark edge, which gave the appearance of dark rays in the corona. (The origin of such dark rifts in a three-dimensional corona is a matter for interesting reflection. Filiform shadows or filiform regions free from luminous matter could hardly appear as dark rifts, and we are left with alternatives (1) of rifts of small breadth, but of great depth and length, or (2) of raylike regions of strongly absorptive matter, or (3) of a corona in which the luminosity is, on the whole, confined to rays. Analogous reflections as to the origin of the contrast between the

dark and bright rays often seen at sunset near shade-producing clouds lead one to the simple supposition that the light-scattering particles are mainly confined to a stratum of air at about the same height as the clouds.)

When thus carefully followed the streamers could be traced very far, till the contrast was far smaller than one would ever hope to catch in a photograph unless it was taken with such precautions as would be needed to portray delicate cirrus cloud. Still I confess it was a surprise to me to find that the furthest extension recorded on any of our photographs is barely  $1\frac{1}{2}^\circ$ , or, say, 3 diameters, as compared with my visual estimate, which gives something less than 6 and more than 5 diameters.

§ 9.—*Visual Observations of the Polarisation of the Earth's Atmosphere during Eclipse.*

A Savart polariscope, mounted with pointer and graduated circle, was pointed to the region of the sky near the eclipsed sun, 30 seconds after second contact. I found the polarisation not very strong; in no position of the Savart were the bands very marked. I was prepared to find vertical polarisation, and the corresponding reading of the pointer when the bands were extinguished by rotating the polariscope in the usual way, would have been  $45^\circ$ , with a white-centred band system at the reading  $0^\circ$ .

The readings were actually  $37^\circ$  in the counter-clockwise rotation.

„ „  $42^\circ$  clockwise „

Without assuring myself that the band system was white centred in the vertical position of the instrument, I interpreted my readings to mean that the plane of polarisation was nearly vertical, and adjusted the photographic instruments (p. 70) accordingly.

Now the actual mean reading  $39\frac{1}{2}^\circ$  meant that the plane of polarisation was inclined either at  $5\frac{1}{2}^\circ$  to the vertical, sloping downwards to the left hand, or else at  $5\frac{1}{2}^\circ$  to the horizontal, sloping downwards to the right. Unmistakable evidence afforded by the photographs shows that the atmospheric polarisation was in the nearly horizontal plane.

The photographic evidence, moreover, shows that at Guelma the atmosphere diffused as much polarised light as was emitted by the corona at a distance of about  $1\frac{1}{2}$  diameters from the moon's limb. (See p. 71.)

These two facts, so important in the study of the polarisation phenomena of the corona, make me regret that by an oversight, resulting from an accident before leaving England, I had omitted to pack the set of five Savart polariscopes prepared for a complete survey of the atmospheric polarisation on lines similar to those in part carried out by Mrs. Newall at

Algiers in 1900. The oversight was discovered a week before the eclipse, and though the instruments were sent out in response to a telegram and arrived two days before the eclipse, it was judged impossible in the then condition of the sky to provide for the rehearsals needed for a proper set of observations.

With reference to the intensity of atmospheric polarisation observed by me at four recent eclipses, the following summary is not without interest:—

|       |          |                                     |
|-------|----------|-------------------------------------|
| 1898. | India.   | Polarisation intense (dry air).     |
| 1900. | Algiers. | „ fairly strong (on the sea-board). |
| 1901. | Sumatra. | „ imperceptible (moist air).        |
| 1905. | Guelma.  | „ rather weak (dry air).            |

If one may hazard numbers on memories I would mark the intensities 10, 7, 0, 3.

There is much to be said for the view that the atmospheric polarisation during eclipses is in great measure due to the fact that the atmospheres diffuses the polarised light of the corona, which in general must have a determinate resultant plane of polarisation, depending upon the distribution of brightness in the radially polarised corona.

#### PHOTOGRAPHIC WORK.

##### § 10.—*Four-prism Spectrograph with Two Slits.*

The same four-prism spectrograph, with two slits, as was used in 1901 in Sumatra and as was described in the 'Proceedings,' vol. 69, p. 220, was used in an attempt to photograph the spectrum of the eastern and western equatorial regions of the corona simultaneously, for a determination by a spectroscopic method of the velocity of rotation of the corona. The only change in the instrument consisted in the piercing of windows in the sides of the tube just in front of the slits, in order to admit of illumination of the slits, if required.

No results were obtained, for the light of the corona at 3' (minutes of arc) from the sun's limb failed to impress the photographic plate. [Mr. Dyson informs me that in his photographs of the coronal spectrum, obtained at Sfax, photographic action on the plate is not seen at greater distances than  $3\frac{1}{4}'$  from the sun's limb.]

Nothing in the preparations or during the eclipse itself was omitted which could have made the attempt successful. The subsidiary photographs of the spectrum of the light of the sky, obtained immediately before and after the eclipse, showed that the instrument was in perfect order. The

image of the corona on the slits looked splendidly bright; the driving of the clockwork was excellent, thanks to the great care that Mr. Champion was good enough to devote to the rating of it. I felt convinced that success was achieved, but in spite of all efforts in development of the plate, no trace of spectrum was obtained.

I decided not to dismount the instrument immediately after the eclipse, but to repeat, in the conditions at Guelma, some experiments made several years ago to test the limits of the light-grasping power of the instrument. Accordingly, a week later, photographs of the spectrum of the moon at first quarter were obtained with various exposures from 20 seconds to 180 seconds; they gave results which, taken in connection with the results of the photographic investigations of the polarisation of the corona, prove that the use of so powerful a spectrograph was based on too sanguine hopes as to the brightness of the corona at 3' from the sun's limb, even under the exceptionally favourable conditions experienced at Guelma. I am led to infer, from the strength of the spectrum obtained on September 5 by an exposure of 20 seconds to the moon's limb at first quarter, that the unpolarised light of the corona at 3' from the sun's limb cannot be as bright as one-eighth of the brightness of the moon's surface. Turner's law of brightness, which refers to the total (polarised and unpolarised) light of the corona, would show that the brightness at 3' is one-third of the brightness at the sun's limb.

#### § 11.—*The Cœlostæt and the Fixed Cameras.*

The cœlostæt has a mirror of silvered glass 16 inches (40 cm.) in diameter, worked by the late Dr. Common, to whom eclipse observers are so much indebted for his development of the cœlostæt method. The mounting was made by Cooke and Sons, of York, and the instrument was used to supply light to seven fixed cameras described in the following paragraphs. This instrument has been constructed with a view to its being mounted for solar observations at Cambridge. By a fortunate coincidence it happens that the latitude of Cambridge is little different from the co-latitude of Guelma, and thus it was possible to design the instrument so that it would serve for observations in Algeria if the wedge-shaped casting that supports the polar axis on its hypotenusal face were overturned, the side that is to be vertical at Cambridge being laid approximately horizontal at Guelma. Mr. Wallace succeeded admirably in rating the excellent clockwork supplied with the instrument.

The incidence of the coronal light on the mirror was arranged to be approximately  $15^{\circ}$ . Thus the reflected beam was of elliptical section with

minor and major axes respectively 15 and 16 inches. The small incidence of the light on the silvered glass could not give rise, as was proved by direct experiments of a delicate nature, to polarisation effects of a kind likely to interfere with the polariscopic observations.

The azimuth and altitude of the sun were calculated to be  $53^{\circ} 52'$  and  $50^{\circ} 38'$  respectively, at the time of mid-totality. The various instruments which were to be supplied with light were fixed parallel to one another on a brick pillar, and were pointed downwards towards the cœlostæt in a direction whose azimuth and altitude were  $60^{\circ}$  and  $21^{\circ} 10'$  respectively on the day of the eclipse.

The sun's declination was changing from day to day by amounts that made it impossible to fix the instruments at the outset in their final position, without forfeiting the chances of utilising the sunlight for adjusting purposes. Accordingly the faggot of instruments was built together on the top of the rectangular box known as the double tube, which served as a camera with partitions in it for three of the instruments. The whole faggot was then bodily moved on the fixed pillar from day to day to suit the sun's declination, and it was firmly fixed in final position on the morning of the eclipse.

The following instruments were supplied with light from the cœlostæt:—

1. The Dallmeyer objective of 4 inches aperture used with a negative lens to give a magnified image of the corona for measurement of the brightness: diameter of the moon 1.5 inches, on plates  $6\frac{1}{4}$  inches  $\times$   $6\frac{1}{4}$  inches. (See § 13.)

2. A Cooke objective of 1.5 inches (37 mm.) effective aperture, giving images of the corona for comparison with the polarised images taken simultaneously with the Savart camera (No. 3), and with the Nicol camera No. 4; diameter of the moon 0.4 inch (10 mm.). (See § 14.)

3. The Savart camera of 1.5 inches (37 mm.) effective aperture, with a large Nicol prism and Savart plates, each 14 mm. thick, in front of the objective, to give an image of the corona with Savart bands for investigation of the polarisation of the corona. (See § 14.)

These three instruments were arranged in the "double tube" which was provided with nine double plate-holders, each carrying two plates ( $6\frac{1}{4}$  inches  $\times$   $6\frac{1}{4}$  inches) which could be exposed simultaneously by a quarter turn of one shutter; one of the two plates in each exposure received two images, separated along a diagonal and impressed by cameras Nos. 2 and 3 respectively.

4. The Nicol camera, consisting of a Cooke photographic objective of 2 inches (51 mm.) effective aperture and 66.8 inches (170 cm.) focal length,

used with an exceptionally large and fine Nicol polarising prism which transmitted a 2-inch beam and gave an image of the moon 0.65 inch (17 mm.) in diameter. (See § 15.)

5. A photographic objective-grating camera with a Rowland grating of ruled surface 5 inches  $\times$   $3\frac{1}{2}$  inches (126 mm.  $\times$  90 mm.) and 14,438 lines to the inch, in front of a 4-inch photovisual object-glass of focal length 72 inches, by Cooke and Sons of York. This camera was supplied by light from the cœlostæt beam by means of an auxiliary silvered mirror which reflected the light in such a way as to give the crescents conveniently disposed with respect to the plane of dispersion. The axis of the camera was below the main faggot of instruments and at right angles to its length. (See § 16.)

6. A polarising spectrograph, arranged in such a way as to throw two polarised images of the spectrum of the corona side by side on the same photographic plate, for comparison of the tangential and radial components of the coronal light at different parts of the spectrum. (See § 17.)

7. A simple camera of short focus (11 inches) and aperture  $f/7.5$  to give a small picture of the corona with long extension of streamers. This was supplied by a totally reflecting prism, which was set in the cœlostæt beam and sent the light downwards in a vertical plane. (See § 18.)

The accommodation of these instruments within a single hut, covering a ground plan 10 feet 6 inches  $\times$  15 feet 2 inches, needed careful arrangement. Four pillars were built, one for the cœlostæt, another for the four-prism spectrograph, a third for the fixed cameras, and the fourth for the objective grating camera.

### § 12.—*The Signals for the Operations During the Eclipse.*

The signals for the operations were given partly from chronometer readings, but chiefly from observed length of the disappearing crescent of the photosphere. Seconds were counted aloud in time with the beats of a carefully adjusted metronome. Each observer recorded the epochs of his operations in terms of the count, except myself, for whom Mrs. Newall recorded.

All observers were at their stations at attention for several minutes before second contact. Mr. Wallace, who had charge of the double tube camera and was watching the image of the disappearing crescent upon the blue focussing plate of the Dallmeyer telephotographic camera, called out the signal "Stand by," when the length of the crescent fitted a template which I had supplied him with and which was calculated to give the length of the crescent at 32 seconds before second contact. At the signal, Mr. Champion began

counting with the metronome and continued it until the signal "Go" was given by Mr. Wallace at the moment of disappearance of all photospheric light. This occurred just after Mr. Champion called "29." Then Mr. Wadmore began a fresh count from 1 up to 60 and again from 1 to 60. Next Mr. Champion renewed the counting through the third minute in intentionally monotonous voice, the entry upon the fourth minute being indicated by a change of voice, which was to denote that the last 35 seconds of totality were passing. He continued counting after third contact, until released by myself, who, after the operations for the second flash spectrum, compared his count with the chronometer, so as to get the chronometer reading corresponding with the count at any moment during totality.

Each observer was instructed as to the duration of the desired exposure in his programme. He noted the count at the beginning of each exposure on a paper on which the duration was already recorded, and, by adding the two numbers, he knew up to what count he had leisure to look at the corona. Thus an exposure of 30 seconds began at count 37: the numbers were recorded, and leisure terminated at 7.

Mr. Wallace had charge of the double tube cameras. Mr. Champion set the Savart to the reading, which I gave to him after making visual observations of the atmospheric polarisation; and he also made the exposures for the polarising spectrograph. Mr. Cooke carried out the programme for the Nicol camera, after I had set the graduated scale in the proper position in accordance with the visual observations; his operations consisted in setting the Nicol prism and also making an exposure of 30 seconds, four times during the eclipse. Mr. Wadmore made a long exposure with the short focus camera. Mrs. Newall recorded the epochs of opening and closing whilst I was manipulating the grating camera; and she secured two photographs during totality with the grating camera. My own programme included (*a*) operations with the four-prism spectrograph, viz., taking photographs of the spectrum of the sky about 10 minutes before and after totality and also taking a photograph of the spectrum of the corona during totality; (*b*) operations with the grating camera, involving the focussing of the camera and fine adjustment of the grating to be done about 5 to 2 minutes before totality and making exposures (six for each) for the first and second "flash" spectra; (*c*) making the visual observations of the atmospheric polarisation and then setting the Nicol prism and circle for the exposures with the Nicol camera and also giving the reading for the Savart camera; (*d*) naked eye observations of the extensions of the corona, etc.; (*e*) the exposure to the light of the corona of a photographic plate behind a set of Abney squares for photometric purposes.

All the operations in the programme were rehearsed until each observer

was satisfied that his part was under control. The last of the rehearsals were held on the evening before the eclipse day, both in the twilight and in the dark with lamps and candles, a procedure which was found very helpful as a preparation for the actual eclipse.

§ 13.—*Dallmeyer Telephotographic Camera.*

Nine plates were available for exposure, and were utilised as follows :—

| Plate. | Subject.              | Exposure.                     |                       | Kind of plate. | Purpose of photograph.                 |
|--------|-----------------------|-------------------------------|-----------------------|----------------|----------------------------------------|
|        |                       | Beginning (Guelma mean time). | Duration.             |                |                                        |
| No. 1  | Partial phase...      | h. m. s.<br>1 32 25           | sec.<br>$\frac{1}{2}$ | Ilford Process | For diameter of sun's image.           |
| 2      | Disappearing crescent | 2 0 50                        | $\frac{1}{2}$         | „              | For position angle.                    |
| 3      | Corona .....          | 2 3 33                        | 11                    | „              | For prominences and inner corona.      |
| 4      | „ .....               | 2 4 39                        | 16                    | Ilford Empress | For middle corona.                     |
| 5      | „ .....               | 2 5 1                         | 32                    | „              | For outer extensions.                  |
| 6      | (Not exposed)         | —                             | —                     | Rocket         |                                        |
| 7      | Corona .....          | 2 5 52                        | 16                    | „ .....        | For outer extensions.                  |
| 8      | „ .....               | 2 6 14                        | 8                     | „ .....        | For inner corona and weak development. |
| 9      | Reappearing crescent  | 2 14 47                       | $\frac{1}{2}$         | Ilford Process | For position angle.                    |

Plate No. 6 was not exposed during totality ; it was to be at Mr. Wallace's discretion to expose or not according to the interval needed between Nos. 3 and 4 for the visual observations of the atmospheric polarisation which I was to make. The plate was exposed the day after the eclipse, to get three images of the sun at intervals long enough to ensure the separation of the images ; the resulting negative serves to give the direction of the parallel (daily motion) on the plate.

Sir W. Abney's standard squares were impressed on many of the corona plates just before development. The photographic squares used for reduction of intensity are the same as were used by me in Sumatra in 1901, and were made by Sir W. Abney. In all cases the standard candle was set at a distance of five feet from the plate, and was backed by a black cloth screen. The exposures given for the several plates are entered in the appropriate column below, in a table which gives information about development, etc.

| Plate. | Subject.         | Exposure.             | Development.    | Standard squares.      | Remarks.                                 |
|--------|------------------|-----------------------|-----------------|------------------------|------------------------------------------|
| No. 1  | Partial phase... | sec.<br>$\frac{1}{2}$ | Metol .....     | None .....             | Reversed sun, ugly plate.                |
| 2      | Crescent.....    | $\frac{1}{2}$         | „ .....         | „ .....                | Ditto, ditto.                            |
| 3      | Corona .....     | 11                    | Metol quinol... | „ .....                | Clean negative, extension to.            |
| 4      | „ .....          | 16                    | Metol .....     | 80 sec. and 5 sec. ... | Ditto, ditto.                            |
| 5      | „ .....          | 32                    | „ .....         | 80 sec. and 5 sec. ... | Clean negative.                          |
| 6      | (Not exposed)    |                       |                 |                        |                                          |
| 7      | Corona .....     | 16                    | „ .....         | 120 sec. and 10 sec.   | Long streamer. Sky begins to show.       |
| 8      | „ .....          | 8                     | Weak metol ...  | 60 sec. and 5 sec. ... | Clean negative, detail in middle corona. |
| 9      | Crescent.....    | $\frac{1}{2}$         | Metol .....     | None .....             | Reversed sun, ugly plate.                |

No. 3 shows that the prominences (so brilliant in the naked-eye view of the corona) form a long bank, reaching over  $30^\circ$  round the sun's limb, northwards from the equator, and extending about  $2'$  from the limb radially. The lower corona in its neighbourhood is full of complicated structure.

The other plates show a corona of the type connected with the epoch of maximum in the sun-spot cycle; markedly long streamers are shown, stretching out near the south pole; each of these appears as a double bright ray, with a dark ray in the middle. But the most marked appearance of a dark ray is that on the southerly edge of the longest streamer on the eastern limb of the sun.

#### § 14.—*Savart and Comparison Cameras.*

These two cameras were included in one compartment of the double tube, and, as the exposures were made simultaneously with those of the plates in telephotographic camera, there is no need to repeat here the epochs of the beginning of each exposure.

Notes as to the kind of plate, and the exposures for the standard squares, are given on the next page. Metol was used as developer in every case.

The Savart and Nicol prism were reset between Nos. 3 and 4.

Plate No. 6 was exposed on the day after the eclipse, for three images of the sun in each camera, for the purpose of getting the direction of the parallel on the plate.

Nos. 8, 4, and 5 were taken with durations of exposure in geometrical progression, so that the polarised image on No. 4 might be compared with the unpolarised image on No. 8, and so on.

| Plate. | Subject.                    | Exposure.          | Kind of plate.    | Standard squares.    | Remarks.           |
|--------|-----------------------------|--------------------|-------------------|----------------------|--------------------|
| No. 1  | Partial phase...            | sec. $\frac{1}{2}$ | Ilford Process... | None .....           | Reversed sun.      |
| 2      | Disappearing crescent       | $\frac{1}{2}$      | " .....           | " .....              | Reversed crescent. |
| 3      | Corona .....                | 11                 | Ilford Empress    | 20 sec. at 5 ft.     |                    |
| 4      | " .....                     | 16                 | " .....           | 80 sec. and 5 sec.   |                    |
| 5      | " .....                     | 32                 | " .....           | 80 sec. and 5 sec.   |                    |
| 6      | (Three sun images for each) | $\frac{1}{4}$      | Rocket .....      | None .....           | Reversed sun.      |
| 7      | Corona .....                | 16                 | " .....           | 120 sec. and 10 sec. |                    |
| 8      | " .....                     | 8                  | Ilford Empress    | 80 sec. and 5 sec.   |                    |
| 9      | Reappearing crescent        | $\frac{1}{2}$      | Ilford Process... | None .....           | Reversed crescent. |

No. 7 was the most sensitive plate used, and the development was somewhat forced, in order to bring out faint extensions of the corona. It has turned out to be one of the most interesting plates of the series, for the bands due to the atmospheric polarisation are visible both above and below the sun. These bands are out of step in the band system over the corona, and prove conclusively (account being taken of the visual observations, p. 63) that if the polarisation of the corona is radial, the polarisation of the sky just above and below the sun was nearly horizontal at Guelma. Moreover, it is seen on the negative that the two band systems neutralise one another, and cease to be perceptible along two linear regions above and below the sun at a distance of about  $1\frac{1}{2}$  diameters from the sun's limb. When taken in connection with the visual observations (p. 63) the interpretation of this appears to be that at those points the (approximately) horizontal polarisation of the atmosphere is equal in intensity to the radial polarisation of the corona.

On no other plate of the whole series do there appear any bands due to *atmospheric* polarisation, though by inadvertence, due to a change of plan in my procedure in the matter of adjusting both the Nicol prism and the Savart system, I had given Mr. Champion an instruction to set the Savart system to a reading which differed by  $45^\circ$  from that which I had really intended. By this inadvertence the Savart camera was not used in the way which I consider best: for it was set so as to give the atmospheric bands their maximum intensity instead of extinguishing them. Fortunately, the inadvertence was a blessing in disguise; for it has proved to be the means of making certain about the plane of polarisation of the sky, and also of finding a sort of quantitative relation between the relative amounts of polarisation in the sky and the corona.

With regard to the photographs actually obtained I would point out that,

in spite of the fact that the band system due to the sky must act in a way to diminish the visibility of the band system seen over the corona, yet all the plates show the bands very markedly over the corona, and will consequently form excellent material for a quantitative study of the relation between the polarised and unpolarised portions of the light of the corona; and the interest in this study is heightened by the fact that observations were secured with the same instruments at the epoch of minimum in the sun-spot cycle.

§ 15.—*The Nicol Camera.*

A Nicol prism, with a clear circular aperture of 2 inches, was mounted in front of a photographic telescope of 4 inches aperture and 66·8 inches focal length, the effective aperture being 2 clear inches. The prism was mounted in the usual turning-stand, and a graduated card was fixed so that the Nicol prism might be turned through  $135^\circ$  in three steps of  $45^\circ$  each. The programme was to find the direction of polarisation of the sky, and then to set the Nicol prism in four different positions, namely, parallel and perpendicular to the sky polarisation, and in two other positions each inclined at  $45^\circ$  to the sky polarisation; and in each of the four positions an exposure of 30 seconds was to be given. For convenience in description I shall call the four positions of the Nicol prism  $45^\circ$  E., Vertical,  $45^\circ$  W., and Horizontal, these names indicating the approximate positions of the longer diagonal of the section of the Nicol; the exact positions have been recorded, but need not be here reproduced.

Mr. Cooke made the following exposures:—

| Plate.   | Position of<br>Nicol. | Duration. |
|----------|-----------------------|-----------|
| No. X 1. | $45^\circ$ E.         | 30 sec.   |
| X 2.     | Vertical.             | „         |
| X 3.     | $45^\circ$ W.         | „         |
| X 4.     | Horizontal.           | „         |

The plates were all of Seed's make, "Gilt Edge No. 27." They were developed simultaneously with metol, and in all processes of treatment have been treated simultaneously. No. X 4 was, unfortunately, not completely exposed before sunlight had reappeared, and, though it turns out to be an interesting and fantastic picture, it is useless for comparison with the others.

Nos. X 1, X 2, and X 3 are all excellent plates, and show very considerable detail in the corona, quite apart from the polarisation phenomena exhibited in them.

If the pictorial aspect of the plates is rather spoilt by the appearance of certain rays and some false images, due to internal reflections in the Nicol prism, it is to be hoped that their presence will not much interfere with measurement. In one respect the rays may be conveniently utilised, namely, for exact determination of the position of the principal plane of the Nicol with respect to the sun's axis.

The negatives render obvious to the most casual inspection the radial nature of the polarisation of the corona.

They also give a conclusive piece of evidence as to the plane of polarisation of the sky. For the shadow cast by a diaphragm in the camera on to the photographic plate leaves the margin of the negatives absolutely clear; whilst the actinic power of the sky has impressed itself faintly in all three plates. It is evident that the effect of the sky is smaller in X 2, when the Nicol was approximately vertical, than in X 1 or X 3, when the Nicol was respectively  $45^{\circ}$  E. and  $45^{\circ}$  W. This, taken in connection with the visual observations (p. 63), proves that the sky polarisation was nearly horizontal.

It is, perhaps, rash to speak before having carried out actual quantitative measurement. But a comparison of X 1 and X 3 shows at once a very marked feature. The long streamer which seems to cut across the sun's limb just to the east of the south pole of the sun is very strong in one and almost obliterated in the other; whereas two curved arches, not very far away in the middle corona, remain about equally strong in both pictures. It is very tempting to think that there may be a selective action of the kind. For the researches of Christie, Dyson, and others seem to connect some of these curved arches with outbursts of prominences, and it is not altogether improbable that a change in inherent luminosity of the tenuous matter in the neighbourhood of a prominence might be propagated through the matter in such a way that, when the surfaces were seen in projection, the envelopes were in a sense marked out as apparent arches round the prominences.

What the cause of polarisation in the straighter streamers may be, and, indeed, whether we are to connect marked polarisation chiefly with straight streamers, are questions that would be much elucidated, could we get unimpeachable spectroscopic evidence as to the nature of the light. An attempt of the sort is referred to in § 16, but it is incomplete. If Fraunhofer lines are found in the streamers more strongly than elsewhere, this might be taken as evidence that the polarisation is due to reflection from small particles.

§ 16.—*The Photographic Objective-Grating Camera.*

The Rowland grating used in these observations is part of the spectroscopic installation arranged by the late Professor Piazzzi Smyth. I am under great obligations to the Royal Society for the continued loan of this outfit. The grating is a plane grating with a ruled surface 5 inches  $\times$   $3\frac{1}{2}$  inches on speculum metal, with 14,438 lines to the inch, in all about 72,000 lines. It was fitted on a horizontal axis in front of a telescope of 4 inches aperture and 72 inches focal length, the lens being a very fine photovisual triple object-glass by Messrs. Cooke and Sons, of York.

The programme was to attempt to get: (i) photographs of the flash spectrum with a high dispersion from the green end of the spectrum including the green coronium line to the ultra-violet near K, the photographs to be attempted both at second and at third contacts; (ii) photographs of coronal rings in the same region of the spectrum of the corona during totality.

The breaking of a string used in these operations about 4 minutes before second contact rather upset the even tenor of things, but as photographs were successfully obtained, though not exactly in the form I had originally intended, I need not dwell upon this mishap further than to say that under the stress of the mishap I unfortunately gave way to a doubt as to the correctness of the preliminary rough setting of the grating, and in resetting it I made the very mistake which I thought at the moment I was correcting; for I threw into the camera the *magnified* spectrum of the second order—that is the spectrum got with small incidence and large emergence—instead of the brighter and less dispersed spectrum of the second order, which I had intended to photograph. However, in spite of this mistake, and in spite of the fact that the grating was not used to the best advantage even for that spectrum, the spectrum is satisfactorily recorded on the photographic plate, with a linear dispersion of about 0.4 mm. per tenth metre, over the region of spectrum comprised between the wave-lengths  $\lambda$  4610 and  $\lambda$  5120, which thus extends over about 21 cm. or  $8\frac{1}{2}$  inches, probably a greater dispersion than has ever been attempted for the flash spectrum.

Three sets of photographs were obtained, each on a 10-inch  $\times$  8-inch plate, which was mounted in such a manner that it could be pushed along in its own plane by an inch at a time, and thus as many as seven spectra, each about 9 inches long, could be set side by side on the same plate. A hinged shutter in the camera was closed while the movement of the plate was being made.

The Plate G 1 has on it six spectra of the disappearing crescent. They

relate to the following epochs recorded by Mrs. Newall in terms of the metronome count, whilst I made the exposures :—

|                            |        |        |        |        |        |        |
|----------------------------|--------|--------|--------|--------|--------|--------|
| No. of spectrum ...        | 1.     | 2.     | 3.     | 4      | 5.     | 6.     |
| Count .....                | 17—18  | 20—21  | 23—24  | 27—28  | 29—2   | 7—9    |
| Duration of exposure ..... | 1 sec. | 1 sec. | 1 sec. | 1 sec. | 2 sec. | 2 sec. |

Mr. Wallace gave the signal “Go”—to announce the beginning of totality—just after Mr. Champion had counted “29.” Hence the spectrum No. 5 on this plate was exposed for about half a second to some remnant of photospheric light and for  $1\frac{1}{2}$  second to the flash ; and the photographic record is quite in accordance with the view that the signal was given at exactly the right moment. Spectra Nos. 1 to 4 show the dark photospheric lines in crescent shape and also a very broad and bright  $H_{\beta}$  crescent. No. 5 is full of bright and well-defined crescents. Spectrum No. 6 shows only the  $H_{\beta}$  line.

The Plate G 2 has on it two spectra of the corona, one with exposure of 6 seconds, from the count 15 to 21, the other with exposure of 159 seconds from the count 21 to the end of the third minute, both exposures being made by Mrs. Newall. No coronal rings are visible in the range of spectrum photographed.

The Plate G 3 was exposed by me five times to the reappearing crescent, but, unfortunately, I just missed the flash spectrum by waiting a trifle too long before beginning the exposures.

### § 17.—*The Polarising Spectrograph.*

The spectrograph was a single prism instrument which transmitted a 2-inch beam through the prism. An excellently corrected objective by Cooke, of aperture 2 inches and focal length about 20 inches, was used to throw an image of the corona on the slit. A large double-image prism of square section 2 inches in the side and producing a separation of  $3^{\circ}3'$ , was inserted between the dispersive prism and the objective of the camera. Had the double-image prism been absent two spectra, due to the two regions of the corona falling on the slit, would have appeared on the plate, with a dark space between them due to the dark body of the moon. The action of the double-image prism was to give two images of these pairs of spectra without any overlapping, and they were arranged so that one was due to the tangential polarised component and the other to the radial.

The programme of exposures was to get two exposures, one of 20 seconds for the inner corona, the other of 120 seconds for the outer corona as well. Unfortunately the second exposure was spoilt by the admission of sunlight.

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The short exposure gave a good negative. It was taken on a Seed orthochromatic plate, and shows the spectrum from the yellow to the ultra-violet just beyond K.

The radially polarised images are very much stronger than those tangentially polarised; and this is true for both sides of the corona.

The spectra extend about 5 to 7 minutes of arc from the sun's limb, and fade off gradually to the limit, in such a way that had Fraunhofer lines been present they could readily have been detected. No such Fraunhofer lines can be traced in any of the spectra. In all the four images on the negative, the marked feature is the strength of the continuous spectrum. The lines of coronium are relatively feeble at both points of the corona that fell upon the slit.

There is no trace of light, in either image, across the body of the moon.

### § 18.—*The Short Camera.*

One negative was secured with the short camera of focal length 11 inches, which was provided with a rapid rectilinear lens of aperture  $f/7.5$ . An exposure of about 170 seconds from the count 40 to the count 3 minutes and 30 approximately was given to it, and it was slowly developed until the effect of the sky began to appear on the plate. The longer streamers appear well defined, and show extensions not greater than  $90'$ , or nearly 3 diameters from the limb.

### § 19.—*Development of the Photographs.*

The development of all the photographs was carried out at Guelma in one of the class rooms of the school on the following nights:—August 31, 9 P.M. to  $5\frac{1}{2}$  A.M.; September 1, 9 P.M. to  $2\frac{1}{2}$  A.M.; September 2, 9 P.M. to  $1\frac{1}{2}$  A.M.; and September 3, 9 P.M. to  $3\frac{1}{2}$  A.M. The class room was very convenient in both in size and airiness for such operations as imprinting standard squares on the plates. As the temperature was seldom below  $80^{\circ}$ , plenty of ice was needed, and was fortunately procurable from an ice factory in the town. An alum bath was used for every photograph, and not a single plate was lost.

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